



CONTROL - DISPLAY INTEGRATION PROGRAM

AD 655 111

SYNTHESIZED ADI FOR PITCH-SCALE APPRAISAL

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AFFDL-TR-67-36

**SYNTHESIZED ADI FOR PITCH-SCALE
APPRAISAL**

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ABSTRACT

A Photographic Instrument Synthesizer System was developed to provide an economical approach to the evaluation of new concepts in aircraft instrument design. The synthesizer system presents these concepts in the form of a 16 mm motion picture which enables instrument designers to view a proposed instrument in a dynamic mode prior to prototype development.

The Control Systems Research Branch of the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, conducted a series of six studies synthesizing an attitude director indicator (ADI) for a variety of pitch-scale appraisals. An iterative approach was used to develop the instrument concept. Each film was revised to incorporate the changes recommended from the appraisal of each preceding film.

This report provides an engineering description of the six instrument concepts and discusses the results of each film review. The first four concepts are concerned with modifying the aircraft symbol to increase pitch scale readability. The last two concepts are concerned with an expanded pitch scale superimposed on the attitude sphere. The intent of these concepts is to provide information to aid instrument designers in developing an ADI with increased readability.

FOREWORD

This report was prepared by Link Group, General Precision, Inc., Binghamton, New York, under Air Force contracts AF 33(615)-2895 and AF 33(615)-3952. The contracts were initiated under Project No. 6190 "The Air Force Control-Display Program," Task No. 619004 "Control-Display Evaluation." The work was performed at the Air Force Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Mr. Robert R. Davis, Flight Dynamics Control Systems Research Branch (FDCR), was the Air Force Program Monitor and Mr. John H. Kearns, III, served as cognizant Air Force Project Engineer.

This report covers work conducted from 5 November 1965 to 30 June 1966. This report was prepared by Mr. Samuel H. Bordonaro, Link Technical Publications. The manuscript was released by the authors in March 1967 for publication as a technical report.

Significant contributions were made by Mr. W. R. Austin, Senior Project Engineer, Mr. E. Kirk, Artist-Illustrator, and Mr. D. Sykora, Project Engineer, all of the Link Group engineering staff. Their individual and cumulative efforts are gratefully acknowledged.

This technical report has been reviewed and is approved.



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SECTION I

INTRODUCTION

Most aircraft instruments in use today are the products of a slow and expensive evolutionary process. Prototype instruments are fabricated by instrument manufacturers who follow the design and specifications set forth by instrument designers. When the prototype instrument is tested, it often does not meet the display requirements. The prototype is usually "shelved," or attempts are made to modify it to meet the display requirements. If instrument designers could see the proposed display in a realistic dynamic mode prior to finalizing the design, then the time lapse between design and the finished product could be shortened. The Control Systems Research Branch of the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, is attempting to reduce this time lapse by using a Photographic Instrument Synthesizer.

The synthesizer system presents new concepts of instrument design in the form of a 16 mm motion picture which reduces the need for prototype equipment. Use of the film enables the instrument designer to resolve many questions about the color, shape, size, scaling and the basic philosophy of the display under investigation. This analysis is accomplished at a considerable savings in time and money. In this capacity, the Photographic Instrument Synthesizer System assumes an important position in the process of instrument development; it becomes the bridge between the concept and the construction of a prototype instrument which normally precedes the actual aircraft flight instrument:

1. DEVELOPMENT OF DISPLAY CONCEPT

Before proceeding further, the reader should understand how new display concepts are developed on the Photographic Instrument Synthesizer.

Referring to Figure 1, the movable display elements of a proposed instrument are represented by artwork on a large canvas belt. The belt is driven through a rotational and a linear displacement in response to corresponding flight parameters that have been derived from the ME-1 Simulator (characteristics of T-39 jet aircraft). The bezel and other fixed elements of the instrument are cut from cardboard, painted, and placed in front of the movable belt. The representation of the instrument at about three times normal size reduces the need for very delicate and time consuming artwork. The belts and associated masking can be readily removed to accommodate different artwork presentations; this procedure is simple enough to encourage the introduction of a variety of schemes to illustrate some new design concept.

As many as four functions associated with the proposed instrument can be derived from the ME-1 Simulator, converted to digital form, and recorded on punched paper tape. This recording is made in real time as the mission is being flown. The playback and photography is done at about one-tenth real time to allow for the movement of the display and the operation of the camera. Two of the four functions on the paper tape can be selected and decoded to drive the display servos. These servos are controlled individually; the rotational servo is driven, then the linear servo, and finally, the camera is advanced one frame. The display is actually at a standstill each time the picture is taken. At the completion of this sequence, the punched tape is advanced through the next group of data and the process is then repeated.

In cases where more than two functions are to be synthesized, the film is rewound to the starting frame and another exposure is made of the additional artwork representing these functions. Of course, this procedure demands precise frame count and lighting control. The Bolex 16H Camera, which is currently part of the system, meets the frame count and rewind requirements. Lighting control has resulted from extensive experimentation in the effects of light temperature, intensity, and the reduction of light from extraneous sources.

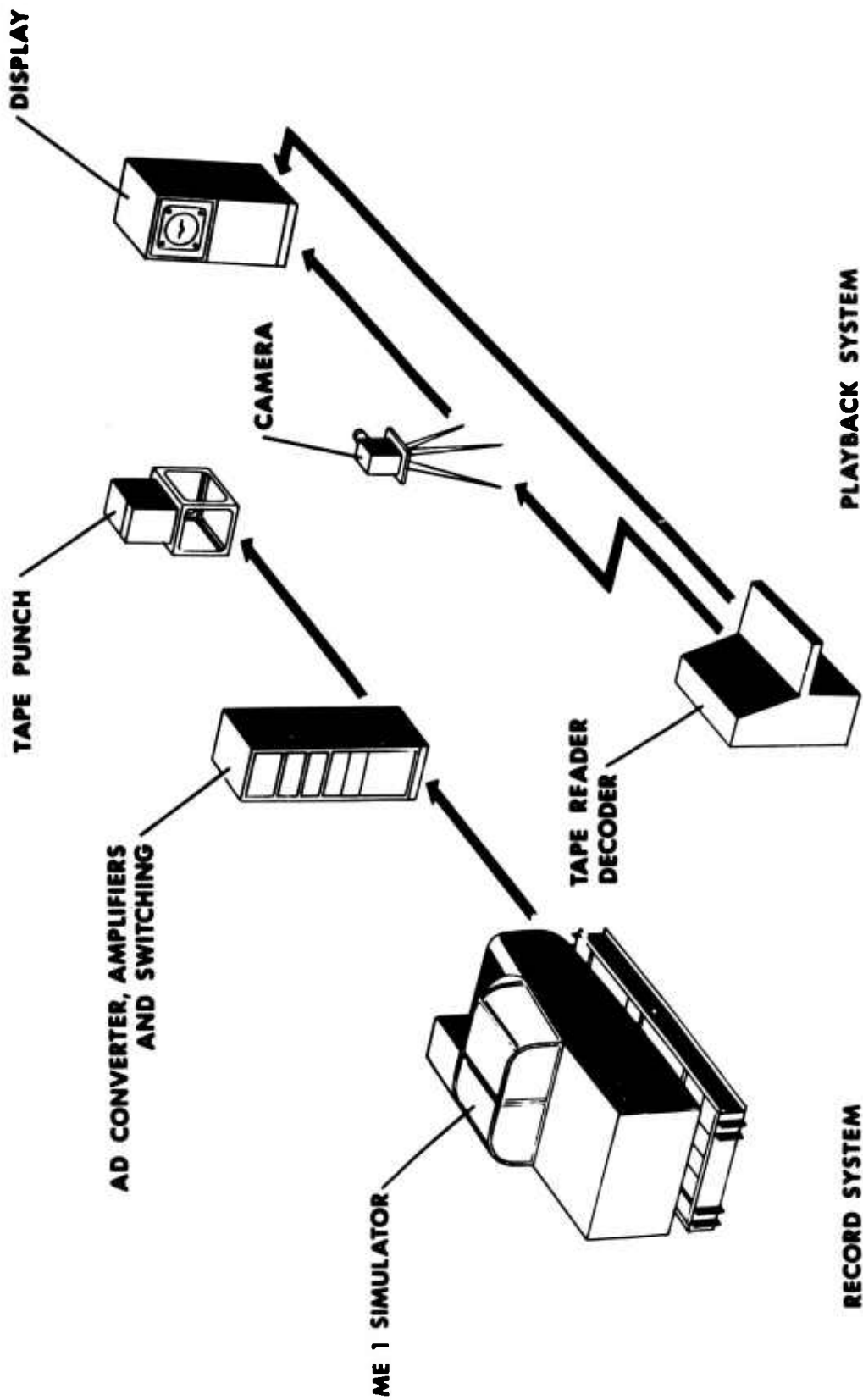


Figure 1. Photographic Instrument Synthesizer System

This system has proved to be an extremely valuable research tool and its utilization is in ever increasing demand.

2. EVALUATION PROCEDURE

The Control Systems Research Branch uses an iterative approach in developing a film-animated instrument display concept. Information that is obtained as a result of evaluating the first film is incorporated into the next iteration, and the concept is continually refined until an optimized film-animated display is obtained.

A formal opinion survey is then conducted, through an open-ended questionnaire, to elicit opinions from the pilots and engineers. Since, ultimately, it is desirable to have a series of questionnaires which will be applicable to the preliminary evaluation of film-animated concepts, the questionnaire represents a first generation measurement device. The objective of the questionnaire evaluation is to determine: (1) the potential merit of the display concept; and (2) to obtain suggestions for improving the display format.

A series of film-animated displays may be developed depicting a single instrument concept. A library of the film-animated instruments is maintained in the Simulation Facility (Bldg 434) of the Air Force Flight Dynamics Laboratory. A new film reference number is assigned to each film; however, the instrument title is retained throughout each series. Film clips of each iteration may be spliced together and a complete evolution of a proposed display concept can be viewed.

3. SYNTHESIZED ADI FOR PITCH-SCALE APPRAISAL

In early 1965, the Control Systems Research Branch produced the first film-animated instrument on the Photographic Instrument Synthesizer. This first effort was to investigate the stroboscopic effects produced by relatively fine lines placed along the horizontal axis of the attitude sphere in an attitude director indicator (ADI). The information gained from this film was passed on to instrument design engineers for incorporation into the construction of a simulator instrument. This unit was subsequently built and tested. A complete description of this first film is presented in an Air Force Flight Dynamics Laboratory Technical Report, AFFDL-TR-65-147, Synthesized Instrument Evaluation.

In November 1965, the Control Systems Research Branch started a series of studies on a synthesized ADI for pitch-scale appraisals. The purpose of these studies was to evaluate dynamic relationships in an attitude indicator which are relevant to a revised pitch scale and read-line reference.

The revised pitch scale incorporated one-degree graduations in the range between ± 20 degrees with emphasis at each 5 and 10-degree interval. The pitch read-line was treated in a manner which allows precise reading without obscuring the area to be read.

A total of six animated films was made, and each film incorporated the changes recommended from the appraisal of each preceding film. The last two films were subjected to a formal opinion survey to gain opinions from pilots and engineers as to the relative merits of the display concept.

The purpose of this report is to provide an engineering description of the six animated films and the suggested improvements for each design iteration. The evaluation of the first four iterations was conducted on an informal basis by in-house personnel. The information contained herein is from an engineering viewpoint, and does not represent the results of the pilot opinion survey. Bunker-Ramo Memorandum Report No. 66-15, Pilot Opinion Survey of a Moving Tape Vernier Pitch Display Concept written under contract No. AF 33(615)-5225, discusses the formal evaluation of the last two iterations.

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This report is divided into three sections. Section II provides an engineering description of each concept and discusses the results of the informal film review. Section III provides a summary of the entire report.

SECTION II

DESCRIPTION

1. REVIEW OF EARLY FILMS

The original films produced on the synthesizer system explored various methods of indicating small changes (1° or less) in aircraft pitch angle. Fine lines were placed on the film-activated ADI parallel to the artificial horizon. The intent was that a slight movement of these lines behind the fixed aircraft symbol would produce a stroboscopic effect which would be more obvious than the movement itself. However, the stroboscopic effect did not occur while the instrument indicated a zero bank condition.

The introduction of a small bank angle completely changed the display; a small movement in pitch was clearly indicated by the running strobe lines. This suggests that the fine lines should not be placed on the instrument parallel to the horizon, but should be displayed at a small angle to the horizon -- perhaps in a crosshatched pattern.

The program for instrument motion was repeated to permit an evaluation of three types of artificial aircraft symbols and color. The first symbol was painted white and was placed very close to the ball of the instrument to minimize shadows. The sections of the symbol that serve only as support were painted black. The same configuration was used for the second film, but the colors were reversed. A new symbol was constructed for the third film and it was purposely placed at a distance from the display to develop a shadow around the aircraft symbol. In actual application, this white aircraft symbol would be painted with a fine black outline; the shadow in this movie averted the need for delicate painting.

Each of the first two symbols were effective only against a contrasting background. The third symbol was made of contrasting colors and was clearly discernible against all the background colors of the instrument. All three symbols revealed a definite need for a more pronounced horizon reference line.

2. SYNTHESIZED ADI FOR PITCH-SCALE APPRAISAL

The review of these early films readily demonstrated the advantages of this type of instrument evaluation. The basic concept investigated in the early films had sufficient merit to further the study with additional films of improved versions.

During a seven-month period, November 1965 to June 1966, a total of six animated films was made synthesizing an ADI for a variety of pitch-scale appraisals. The following paragraphs provide an engineering description of each revised concept and the results of the informal evaluations of the first four iterations.

a. Film Ref. 65-157 - First Iteration

The purpose of this first effort was to produce a film which would depict the revised attitude display as shown in Figure 2. The flight profile that was recorded for the original study was also used on this film. The maneuvers included small pitch angle excursions with bank held constant, and a combination of both pitch and bank within a limited range.

Several preliminary design sketches were made of the various colors and types of lines that might be used for the pitch scale. Following a study of these sketches, the more promising features were transferred to a synthesizer belt. The belt represents the face of the ball of a standard ADI. The top portion of the belt, representing positive pitch, was painted a light blue.

The bottom portion below the horizon, representing negative pitch, was painted brown. The pitch-scale graduations were represented by narrow tapes parallel to the horizon line. The pitch-scale indices were placed at one-degree graduations between minus 20 and plus 20 degrees with emphasis at each 5 and 10-degree interval. Four additional graduations were also provided for plus or minus 25 and plus or minus 30 degrees. The negative graduations for -10, -20, and -30 degrees were white lines; all the rest were black.

The aircraft symbol used on this display consisted of three pointed elements aimed at the center of the display; two were in the horizontal plane and one in the vertical plane. The degree graduation that would show in the center of the pointers would be indicative of aircraft pitch angle. The symbol was painted white and a black center line was placed on the vertical pointer to allow easier reading of the pitch scale in a bank condition.

The black cardboard bezel used through this series of films was a replica of a standard ADI instrument case. The bezel did not show a bank scale because the scope of these studies was confined to pitch scale and read-line appraisals.

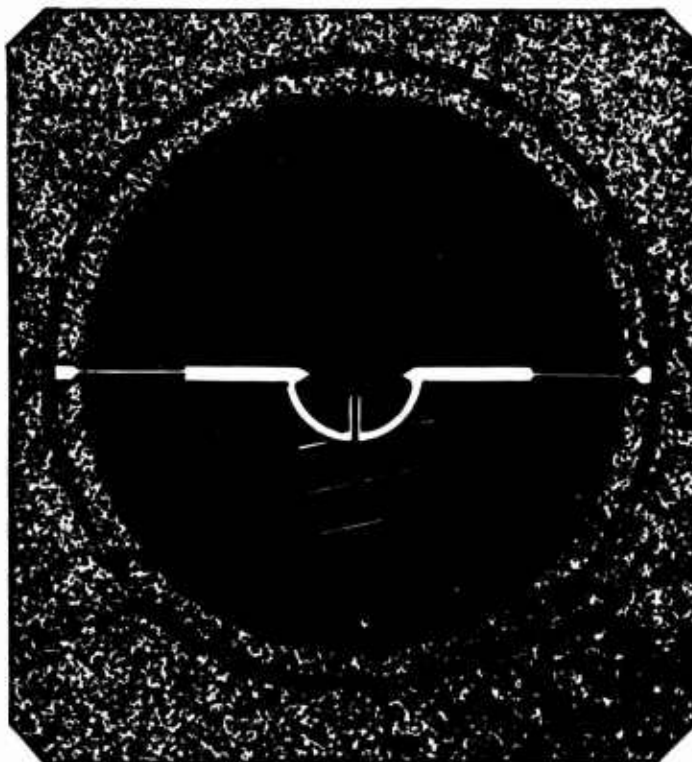


Figure 2. Film Ref. 65-157

(1). Results

The review of the first completed film pointed out several important facts:

(a). The black line on the pointed vertical element of the aircraft symbol was too heavy. It obscured the tip of the vertical element because it blended with the black of the pitch scale.

(b). The aircraft symbol was placed too far from the belt. Therefore, a shadow was created giving the illusion that the symbol was larger than it really was.

(c). The connecting elements of the aircraft symbol should have been thinner, painted black, and the total read-line assembly smaller to permit better alignment. The thickness of the mounting elements prevented precise alignment with the horizon line.

The conclusions reached from this first film are that all portions of the read-line assembly must be made proportionately narrower and the assembly should be recessed to assist alignment and minimize shadows. Also, the black center line on the vertical part of the read-line assembly needs to be removed from the tip in order to gain the desired pointer effect.

b. Film Ref. 65-158 - Second Iteration

The purpose of this second attempt was to produce another film which would represent a sequel to the work covered on Film Ref. 65-157 and which would show additional revisions as determined from the evaluation of the 65-157 film.

The specifications involved on this project included the following steps (Figure 3):

1. Decrease the width of the read-line assembly to approximately 60% of the original.
2. Remove 0.10 inch of black line at the tip of the vertical portion of the read-line assembly.
3. Reduce the thickness of the connecting elements of the read-line assembly and paint them black.
4. Recess the entire assembly to facilitate alignment and reduce shadows.
5. Add black masks to enter the circle about 1-1/4 inches on each side changing the circular display area to a rectangular area with elliptical curves on the top and bottom of the display face (Figure 3). Adding the vertical side masks to the circular opening will accentuate the bank change.
6. Devise a "Film Titler" to show appropriate administrative information (Figure 4). The film titler will be used on all subsequent films produced on the synthesizer.
7. Use the 65-157 belt and recorded program without modification.

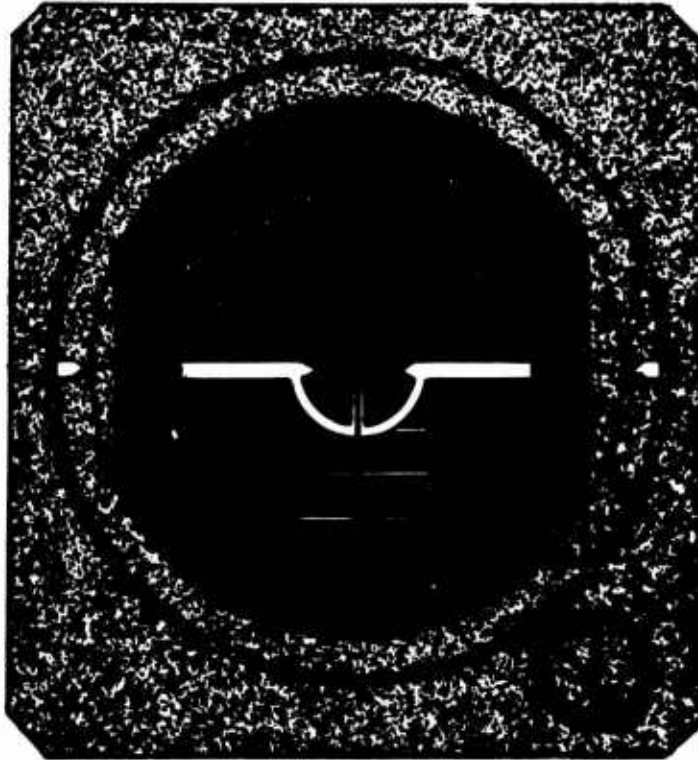


Figure 3. Film Ref. 65-158

Title

Film Ref. No.

Date

Film Library No.

FDCR Task No. 619004

Simulation Facility - Bldg. 434 - Area B

AFFDL - W-PAFB, Ohio

Figure 4. Film Titler

(1). Results

The review of this second film indicated that the quality had increased considerably. The shadows and misalignment that were evident in the 65-157 film were not evident here because the read-line assembly was recessed. The pitch scale was easier to read because of the reduction in size of the read-line assembly. The read-line assembly was in proper proportion with the pitch scale. The mounting elements were thinner and hidden from view due to the black color. Bank changes were clearly pronounced due to the addition of the side masks on the face of the animated ADI.

In order to show the contrast between the two read-line assemblies, it was decided to continue with one more film showing a revised read-line. This revision is described in the following paragraphs.

c. Film Ref. 65-159 - Third Iteration (Figure 5)

The purpose of this attempt was to extend the scope of the preceding investigation in order to compare and evaluate a different read-line configuration. The objective of this comparison was to eliminate read-line "clutter" by using a "cross-hair" arrangement instead of the experimental or conventional read-line assembly. The bezel, belt, and recorded program that were used for the first two films were also used in this iteration.

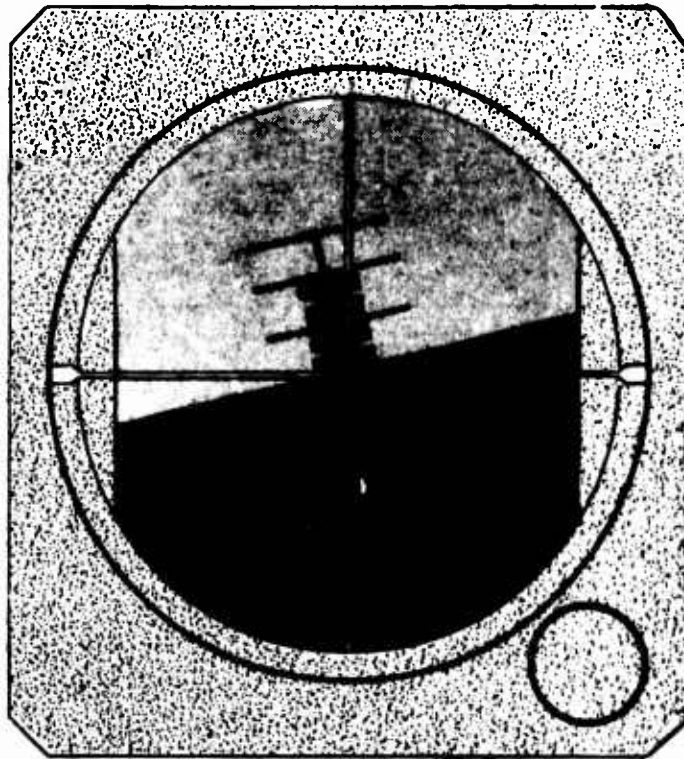


Figure 5. Film Ref. 65-159

In order to form the cross-hair arrangement, two wires were stretched across the back of the bezel. The wire diameter was slightly smaller than the width of a one-degree graduation on the pitch scale. The cross-hair arrangement was painted yellow to provide contrast against the two background colors.

(1). Results

The review of this third film brought out the following points:

- (a). More precise alignment of the horizon and the horizontal cross hair could be obtained.
- (b). Bank changes were more pronounced because the face of the ADI appeared to be divided into four segments by the cross-hair pattern.

(c). The pitch scale was readily identifiable by viewing the junction of the cross-hair and pitch-angle graduation.

(d). The read-line was easily discernible against contrasting background colors.

(e). The obvious disadvantage to this type of read-line is that the cross hair blanks out the degree markings at the junction.

(f). If this configuration was applied to existing flight directors, extensive modification would be necessary to prevent conflict between the cross-hair pattern and existing pitch- and bank-command indicators.

It is evident from the results of the first three films that both concepts have good and bad points. The primary concern of the read-line concepts is to expose as much of the pitch scale as possible and yet be able to have an uncluttered read-line assembly.

d. Film Ref. 65-164 - Fourth Iteration (Figure 6)

The purpose of this fourth film was to enable an evaluation of a read-line assembly that would conform to the general outline of the 65-158 film, but expose more of the horizon line and pitch scale.

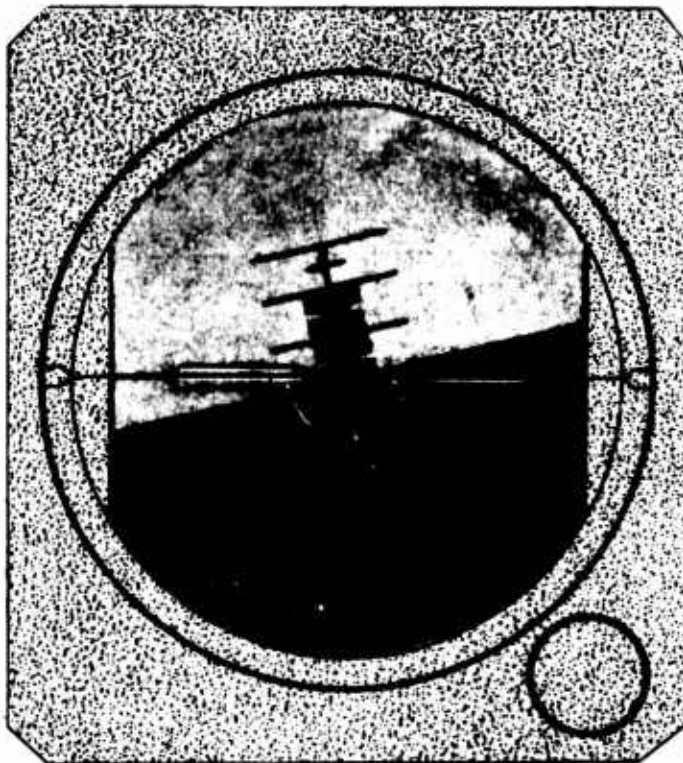


Figure 6. Film Ref. 65-164

A piece of transparent plastic was cut in the same configuration as that used in the first two films. In order to accentuate the read-line assembly, white tape (5/64 in. wide) was placed around the assembly periphery. White tape (1/32 in. wide) was also applied on the horizontal center line as well as the previously used black tape on the vertical center. The mounting elements of the assembly were painted black and the entire assembly was recessed to reduce shadows. The bezel, belt, and recorded program were the same as that used in the three preceding films.

(1). Results

(a). The white center lines on the horizontal bars of the read-line assembly obscured the horizon line of the attitude sphere.

(b). The blue and brown colors of the attitude sphere could not be distinguished through plastic.

(c). The read-line assembly was clearly discernible with the white outline around periphery.

(d). No shadows or glare were evident with this assembly.

(e). The pitch scale was easily identifiable with this configuration.

The first four attempts were concerned with modifying the read-line reference to increase the readability of the pitch scale. It was decided to further the pitch-scale investigation as initiated in Film Ref. 65-157 by implementing an expanded scale configuration. This fifth concept is discussed in the following paragraphs.

e. Film Ref. 65-160 - Fifth Iteration (Figure 7)

In existing ADI's the pitch-scale length is essentially limited by the size of the attitude sphere. In order to increase pitch-scale readability and maintain better attitude control, the instrument size would have to be increased. This is obviously not a practical solution. The concept investigated in this film is an expanded scale (approximately 3:1) superimposed over an uncalibrated attitude sphere. The pitch scale will be read against a conventional airplane symbol as used in existing flight directors.

This version required a new attitude belt, a transparent moving tape with a vernier scale, a conventional reference symbol, and a new recorded flight program. The expanded scale ADI operates in a manner similar to that of a conventional ADI. For example, in depicting a 10-degree pitch-up attitude, the attitude belt moves downward in a normal fashion and simultaneously the tape moves downward until the 10-degree pitch index mark is aligned with the "wings" of the aircraft symbol. Because of the difference in scale factors, the rate of movement of the tape is approximately three times greater than that of the attitude sphere.

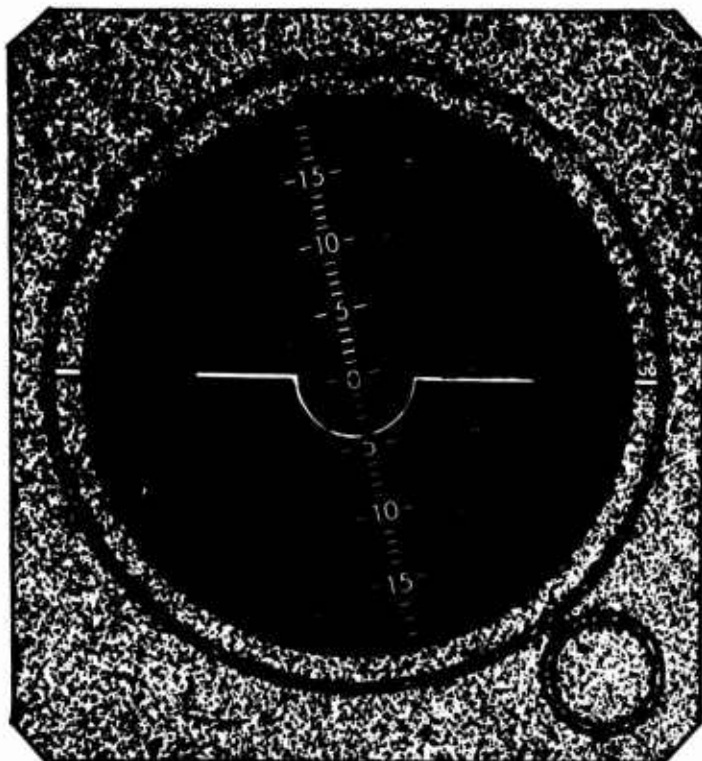


Figure 7. Film Ref. 65-160

In order to animate this concept, it was necessary to double-expose the film to obtain two different rates of movement in the same axis. The attitude belt used for this concept consisted of a normal blue-to-brown horizon line from which the pitch scale was omitted. The flight maneuvers were the same as for the preceding films; however, the pitch input that was recorded on the paper tape was increased to three times its original value. The playback system is provided with an axis selector switch to provide proper scaling and appropriate axis selection.

The first exposure was of the basic functions of the instrument: pitch, roll, and horizon reference line at normal pitch and roll rates. No numerical scaling appeared on the background during the first exposure. The aircraft symbol was painted white and the mounting elements were black.

The second exposure added the transparent expanded pitch scale. This scale moved normally about the roll axis, but the travel about the pitch axis was approximately three times greater than that of the attitude sphere. To accomplish this scale expansion, the film and the punched paper tape were rewound to the exact starting point. The proper scaling and axis selector switches were activated on the playback panel. The attitude belt was removed from the display and replaced with the transparent pitch scale. Pitch graduations were marked on the transparent tape for single degrees of pitch and were numbered every 5 to plus and minus 30 degrees. The numerals and index marks representing positive pitch angles were white, while negative indications were yellow. When the pitch scale was properly aligned at the same starting point as the attitude belt, the program was repeated thereby double-exposing the film.

(1). Results

When the processed film was informally evaluated, the following points were noted:

(a). The digits in the expanded scale were too large. As a result, the zero reference point did not stand out significantly from the rest of the scale.

(b). The pitch scale was limited to ± 30 degrees. When this angle was exceeded, there were no further pitch references.

(c). The side masks were inadvertently omitted.

(d). When a level attitude was shown, a range of ± 15 degrees was shown on the tape. This represents a threefold expansion in scaling over a conventional ADI. The scale factor on a conventional ADI is approximately one inch for every 30 degrees, while the scale factor in this concept is approximately one inch for every 10 degrees.

(e). The expanded scale concept depicted in this film was clearly discernible. Therefore, to further pursue the expanded scale concept, it was decided to make one more film incorporating the revisions noted in the preceding evaluation.

f. Film Ref. 66-179 - Sixth Iteration (Figure 8)

The purpose of this film, as previously stated, was to further pursue pitch-scale appraisals. In the preceding film, the rolling movement of both the expanded scale and the horizon might confuse the pilot. Therefore, it was decided that the expanded scale in this film would remain vertical. The objective was to make the instrument easier to read. Since the side pieces were inadvertently omitted in the preceding film, they were added in this film.

The specifications involved on this project include the following:

1. All scaling digits, except zero, are to be reduced by one half. This will enable easier reading of all digits, and allow the zero point to be more prominent.
2. Add 60- and 90-degree markings on the attitude belt, using a one-inch black ball to denote +90 degrees. Use black markings to illustrate the ± 60 -degree points.
3. Lock the roll axis so that the expanded scale remains vertical throughout the flight pattern.
4. Add the side pieces.
5. Use the same recorded program that was used in the preceding film.

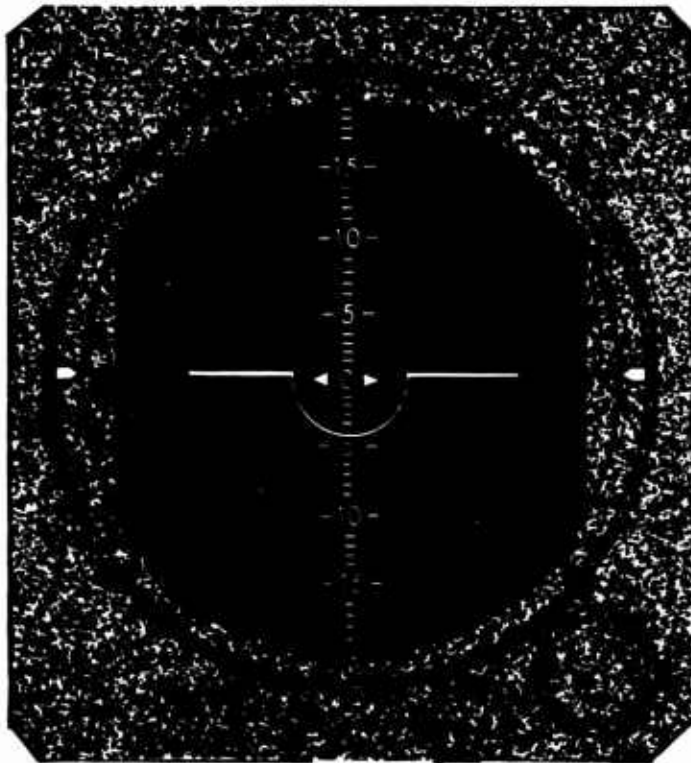


Figure 8. Film Ref. 66-179

(1). Results

The major differences between this and the preceding film are as follows:

(a). In portraying a climbing turn, the preceding film depicted the vernier scale moving downward and rotating with the attitude belt. For the same maneuver, this film shows the vernier scale moving downward, but the tape remains vertical.

(b). In the preceding film, the pitch-scale digits are larger, and no pitch indices are marked on the attitude sphere. In contrast, the scale in this film is numbered up to ± 20 degrees, and the attitude sphere shows pitch graduation marks in 10-degree intervals from plus and minus 30 to plus and minus 90 degrees with numbers at plus and minus 60 degrees. When pitch attitude exceeds 20 degrees, the vernier scale continues to move out of view, and pitch is then read from the markings on the attitude belt. Due to differences in the scale factor, the pitch index markings on the vernier scale overlap the attitude belt markings. Since the vernier scale has a transparent background, both scales of pitch markings can be seen within 20 degrees of pitch.

The concept of both the single-axis and the double-axis pitch scale was clearly discernible. It was felt that both concepts had sufficient merit to be subjected to a formal pilot opinion survey. Film clips of the two instrument concepts were made into photographs to be used as visual aids. A three-dimensional mock-up was also fabricated. The movies and visual aids were submitted to the Bunker-Ramo Corp., Human Engineering Group to conduct the pilot opinion survey. Bunker-Ramo Memorandum Report No. 66-15 discusses the evaluation of the survey.

SECTION III

SUMMARY

The Photographic Instrument Synthesizer System has proved to be a useful tool in developing film-animated instrument concepts. The system provides an economical means of instrument evaluation prior to the construction of prototype equipment.

In early 1965, the Control Systems Research Branch of the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, produced the first film-animated instruments on the instrument synthesizer. The information gained from these early films was passed on to instrument designers. Subsequently, a prototype instrument was built and tested.

Encouraged by the results of the early films, the Control Systems Research Branch started a series of studies on a synthesized ADI. The purpose of these studies was to evaluate dynamic relationships in an attitude indicator which are relevant to a revised pitch scale and read-line reference.

A total of six animated films was produced. Each film reflected the changes recommended from the appraisal of each preceding film. The first four films were concerned with the read-line reference of an ADI. The last two concepts consisted of an expanded pitch scale (approximately 3:1) superimposed over the attitude sphere.

The attitude sphere in all six films used a blue and brown color pattern. Blue above the horizon represented positive angles and brown below the horizon represented negative angles. A variety of pitch-scale graduations and color was used in all iterations.

The last two films, depicting the expanded pitch scale, were subjected to a pilot opinion survey. The results of this survey are discussed in Bunker-Ramo Corp. Memorandum Report No. 66-15 written under contract No. AF 33(615)-5225 entitled Pilot Opinion Survey of a Moving Tape Vernier Pitch Display Concept.

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13. ABSTRACT		
<p>A Photographic Instrument Synthesizer System was developed to provide an economical approach to the evaluation of new concepts in aircraft instrument design. The synthesizer system presents these concepts in the form of a 16 mm motion picture which enables instrument designers to view a proposed instrument in a dynamic mode prior to prototype development.</p> <p>The Control Systems Research Branch of the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, conducted a series of six studies synthesizing an attitude director indicator (ADI) for a variety of pitch-scale appraisals. An iterative approach was used to develop the instrument concept. Each film was revised to incorporate the changes recommended from the appraisal of each preceding film.</p> <p>This report provides an engineering description of the six instrument concepts and discusses the results of each film review. The first four concepts are concerned with modifying the aircraft symbol to increase pitch scale readability. The last two concepts are concerned with an expanded pitch scale superimposed on the attitude sphere. The intent of these concepts is to provide information to aid instrument designers in developing an ADI with increased readability.</p>		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Instrument design Photographic Synthesizer Displays Aircraft instruments Animation Animated aircraft displays Synthesized Attitude Indicators						

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